Discovery

Examination of microbial potential in packed bed on the effect of temperature for petroleum hydrocarbon treatment using adsorbent

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ABSTRACT

The potential of the microbes in petroleum hydrocarbon remediation in a packed bed unit using formulated adsorbent was monitored up on the effect of temperature. The microbes monitored with respect to temperature are classified as mesophilic, thermophilic and super thermophilic and their operational temperatures are Tmim < 20oC and Tmax < 45oC (mesophilic), Tmm < 20oC and Tmax < 75oC (thermophilic) and super thermophilic of Tmim < 20oC and Tmax < 120oC. The research demonstrates the effect of temperature on microbes in terms of microbial growth and petroleum hydrocarbon degradation. The investigation further revealed that the remediation was more of thermal remediation than bioremediation. The performance of the adsorbent was influence significantly by the elevated temperature, because the petroleum hydrocarbon was more of gaseous phase than liquid phase. The rate of microbial activity was high and the rate of contact with the adsorbent was low as well as the potential of the microbes to withstand the condition for their growth was totally inhibited at temperature above 45oC for mesophilic organism, temperature above 75oC for thermophilic organism and temperature above 120oC for super thermophilic.

Keywords: Examination, microbial, potential, packed bed, effect, temperature, adsorbent

1. INTRODUCTION

The growth of microbes in the environment is controlled by various factors, which include temperature, pH, moisture content, oxygen and other physicochemical parameters (A1-Zubaidy et al., 2015; Abbas et al., 2016; Amaku et al., 2021). It is established that variation in temperature influence the microbial activity in bioremediation process as well as its transient growth characteristics (Antonelli et al.,

DISCOVERY SCIENTIFIC SOCIETY

2021; Bull and Rearcion, 2000; Izundu & Philip, 2023). Each microbe possesses the characteristics on the mode of withstanding temperature variation in any given system among the range of low, medium and high (Carberry and Wik, 2001; Cemiglia, 1997; Chen, 2004). The behavior of the organisms when the environment they find themselves are above the required operating temperature, the active site will be inhibited and the ability to reproduce may not be possible (Christoulaki et al., 2014). Some of the organisms may seviver waiting for favourable condition for them to play their role in catalyzing the reaction process (Chukwuemeka-Okorie et al., 2018).

The ability of the microbes to catalyze the reaction depends on the environmental condition as well as the nature of the contaminants or pollutants (Dawodu et al., 2020). In most cases, the nature of the pollutant inhibits the activity of the microbes in degrading the petroleum hydrocarbon. The degradation of the petroleum hydrocarbon may result in the product of other petroleum hydrocarbon products. The metabolic pathway of paraffin by the process of oxidation resulted in series of products produced such as hydroxide compound, aldehydated compound, ketone compound and end products of α, γ, β carbonoxide acid and hydroxide compound (Eren and Baran, 2019; Ezekoye et al., 2020). The oxidation process always occurs at the end of the functional group (Fadhil et al., 2021). And if the functional groups are totally inhibited in most cases, it is difficult for the microbes to feed on the substrate and initiate degradation.

Other important parameters that influence the microbial growth are oxygen, pH etc. It is notice that some microbe's performance is high when the system is aerobic, anaerobic and facultative anaerobic as well as when the medium is acidic, neutral and alkaline in nature (Ukpaka, 2016; Ukpaka et al., 2016). Further research on the effect of physicochemical properties have revealed that turbidity, alkalinity, metals dissolved oxygen (Do), chemical oxygen demand (COD) and other influence the microbial growth especially when concentration is either low or above the recommended standard (USDOD, 1994). Therefore, there is need to check these parameters when carrying out bioremediation programme.

2. MATERIALS AND METHODS

Materials

In this investigation the following common materials were used, which includes: Fresh water, crude oil, fabricated packed bed unit with all electrical units to monitor the temperature, flow rate, pressure, etc. microbial filter, storage tank for sampling, conical flask.

Sample Collection

The fresh water was obtained from Orash River located in Ahoada Town of Rivers State in Nigeria and the crude oil was obtained in Obagi flow station in Ogba/Egbema/Ndoni local government area and transported into Rivers State University Port Harcourt in the department of Chemical/Petrochemical Engineering for experimental set up and sample collection for analysis.

Sample Preparation

The collected agro-based materials were plantain stem, banana stem and Palm fruit fibre and all the materials was sun-dried and room-dried as described PSSD – plantain stem sun-dried, PFFSD – palm fruit fibre sun-dried, BSSD – banana stem sun-dried, PFFRT – palm fruit fibre room temperature, PSRT – plantain stem room temperature and BSRT- banana stem room temperature. These samples were prepared under the influence of sun and room-dried before subjecting it into the packed bed unit connected in series.

Microbial Analysis

Microbial Population Determination

The bioreactor was set-up for the purpose of microbial population of organism's determination in terms counting the unit as defined in Colony forming units/milliter (cfu/ml) in a pour plate of mineral salt agar medium containing 0.5% crude oil. The microbial population was monitored at temperature varies of the bioreactor for both fresh and salt water media contamination as degradation of crude oil was experienced.

Microbial Sample

Total microbial counts were measured by a standard plate count technique using difeo plate count agar. The microbial analysis was carried out at temperature varies for water medium contamination.

3. RESULTS AND DISCUSSION

The effect of temperature on the microbial count concentration was monitored after treatment of the contaminants in each of the packed bed unit within the temperature range of 15oC to 120oC for each of the bio-adsorbent used as well as monitoring the performance with respect the packed bed units connected in series are presented in (Figure 1 to 9).

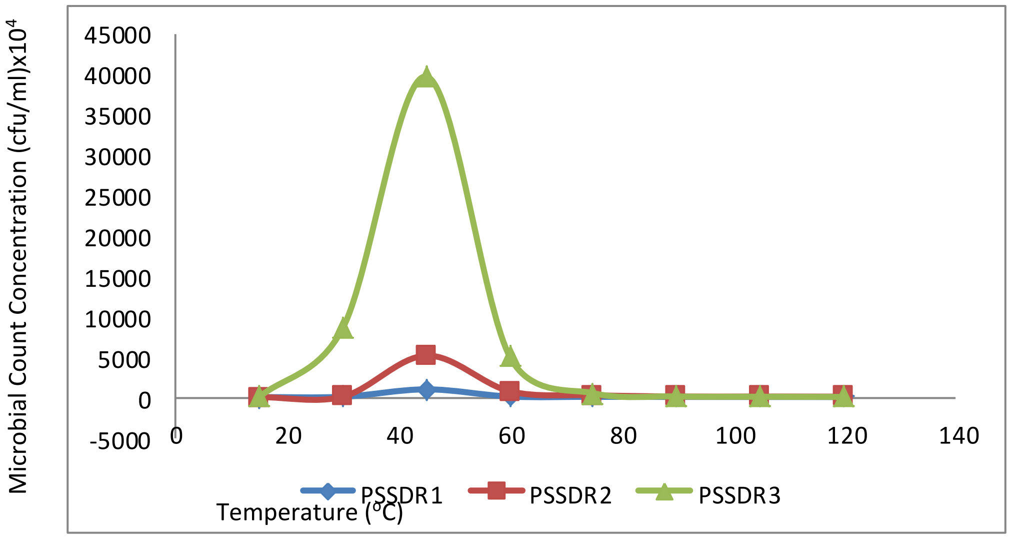

Figure 1 Microbial Count Concentration versus Temperature Effect for PSSD for Packed Bed Units 1, 2 and 3

Figure 1 shows the microbial count concentration of HUB after contaminants treatment from the various packed bed units connected in series. The microbial count concentration increases with the range of temperature 15oC to 45oC before sudden decrease as the temperature increases. This research work reveals that the bio-adsorbent in treatment of contaminants removal is more effective at temperature of 45oC. However, organisms that service at temperature less than 45oC are classified as mesophilic. Furthermore, after the temperature of 45oC a decline in microbial population was experienced.

These characteristics were observed in all the bio-units (packed bed units) connected in series. The thesis also revealed that high percentage of the contaminants are removed at stage 1 of the packed bed unit 1 (U1) followed by unit 2 (U2) and final treatment on unit 3 (U3). The microorganisms play an active role in the bioremediation and degradation of the contaminants increase in microbial count concentration reveals increase in contaminants removal in order of U1 > U2 > U3 upon the effect of temperature. The comparison of the microbial count concentration of the HUB isolated and identified in each bio-unit with the effect of temperature reveals the degree of microbial in this order of PSSDR3 > PSSDR2 >PSSDR1.

Figure 2 evaluates the microbial count concentration of contaminants treatment in a packed bed unit of bio-adsorbent in relationship to temperature effects on the degree of contaminants removal. Indeed, this thesis reveals that the temperature influence bio-adsorbent. Also, the research shows the significance of temperature on the performance of the bio-adsorbent in the packed bed units connected series. The percentage of contaminants removal is in the ascending order of U1 > U2 > U3 and however the packed bed unit is more effective within the temperature range of 150oC to 45oC. At high temperature range of greater than 45oC and above the degree of contaminants removal are distributed to the various units.

This thesis reveals that there is high penetration of contaminants through the bio-adsorbent placed in the packed bed units. On this note the contaminants that passes through the first bio-adsorbent in the packed bed unit (U1) may be trapped in unit (U2) or unit (U3). If the final outlet concentration of the treated contaminants does not meet the World Health Organization Standard (WHO) suggest end product will be subjected with further treatment by the mechanism of recycling using fresh bio-adsorbent packed in the various units

connected in series. Figure 2 showcases the comparison of the microbial count concentration of the HUB isolated and identified in each unit with the effect of temperature reveals the degree of microbial in this order of PFFSDR3 > PFFSDR2 > PFFSDR1.

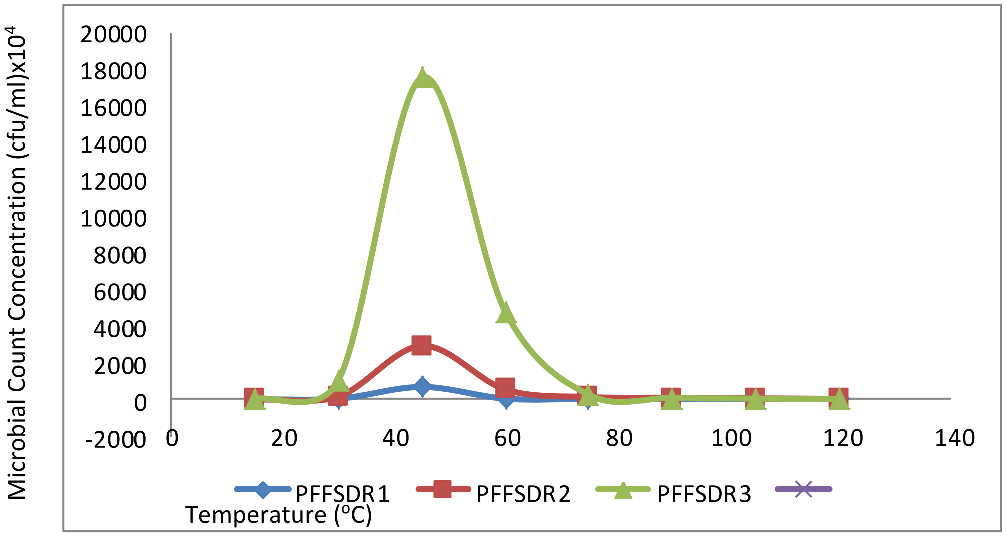

Figure 2 Microbial Count Concentration versus Temperature Effect for PFFSD for Packed Bed Units 1, 2 and 3

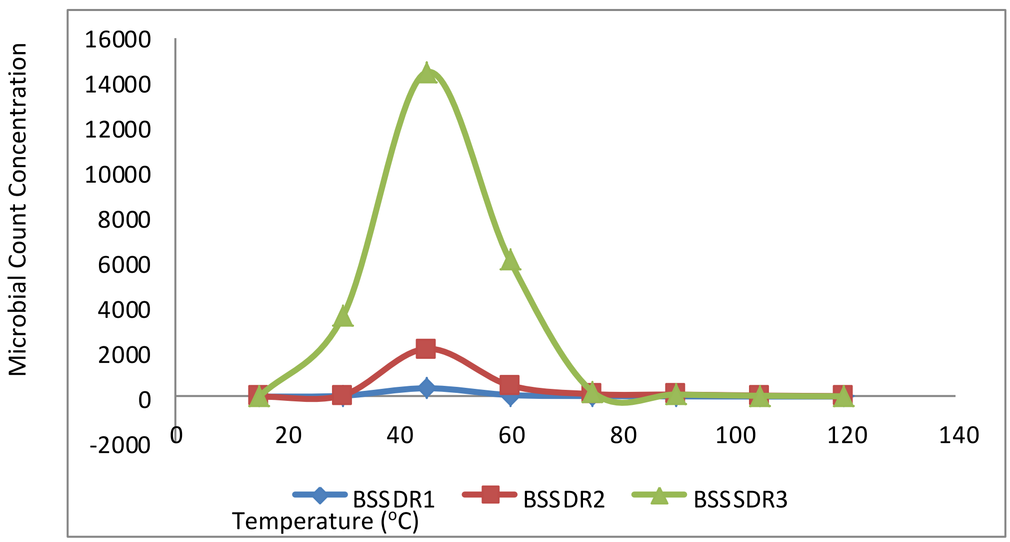

Figure 3 Microbial Count Concentration versus Temperature Effect for BSSD for Packed Bed Unit 1, 2 and 3

Figure 3 demonstrates the resilience of the microbial count concentration on the action of temperature on the treatment of contaminants in a packed bed units connected in series using bio-adsorbent. The effectiveness of the bio-adsorbent is based on the ability of it to reduce the concentration of the contaminants after passing through the packed bed units. This thesis predicts high removal of contaminants from unit U1, units U2 and units U3 within the operating temperature of less 45oC and at temperature greater than 45oC contaminants removal was experienced but the percentage removal is more effective at low temperature as presented in this research work. Indeed, this thesis recommended that the best operating temperature for treatment of contaminated water using bio-adsorbent is within the range of 30oC to 45oC especially when the bio-adsorbent is to be used in the packed bed units. Figure 3 demonstrates the comparison of the microbial count concentration of the HUB isolated and identified in each bio-units with the effect of temperature reveals the degree of microbial in this order of BSSDR3 > BSSDR2 > BSSDR1.

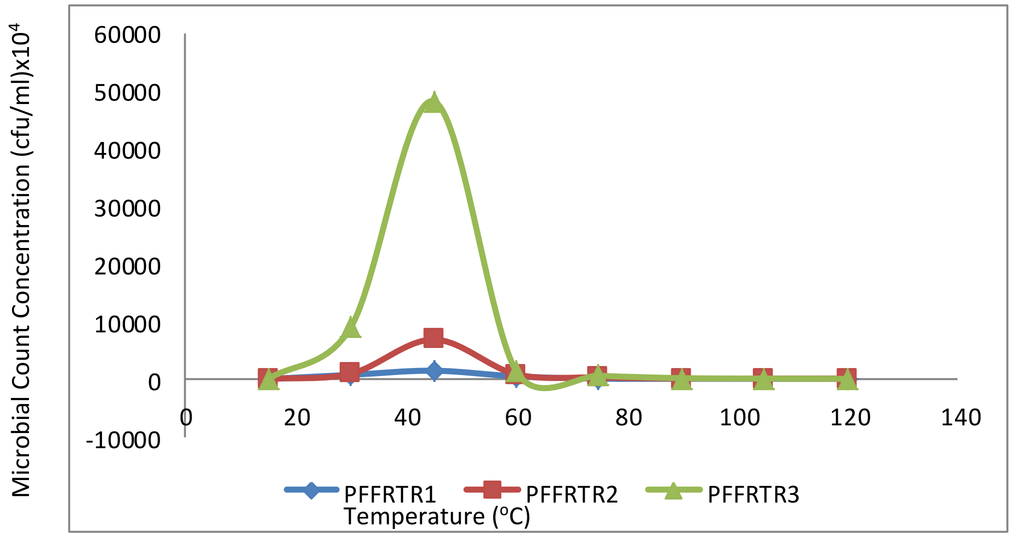

Figure 4 Microbial Count Concentration versus Temperature Effect for PFFRT for Packed Bed Unit 1, 2 and 3

Figure 4 predicts the microbial count concentration of HUB after contaminants treatment from the various packed bed unit connected in series. The microbial count concentration increases with the range of temperature 15oC to 45oC before sudden decrease as the temperature increases. This research work reveals that the bio-adsorbent in treatment of contaminants removal is more effective at temperature of 45oC. However, organisms that service at temperature less than 45oC are classified as mesophilic. Furthermore, after the temperature of 45oC a decline in microbial population was experienced.

These characteristics were observed in all the packed bed units connected in series. The thesis also revealed that high percentage of the contaminants are removed at stage 1 of the packed bed unit (U1) followed by unit (U2) and final treatment on unit (U3). The microorganisms play an active role in the bioremediation and degradation of the contaminants increase in microbial count concentration reveals increase in contaminants removal in order of U1 > U2 > U3 upon the effect of temperature. Figure 4 illustrates the comparison of the microbial count concentration of the HUB isolated and identified in each bio-unit with the effect of temperature reveals the degree of microbial in this order of PFFRTR3 > PFFRTR2 > PFFRTR1.

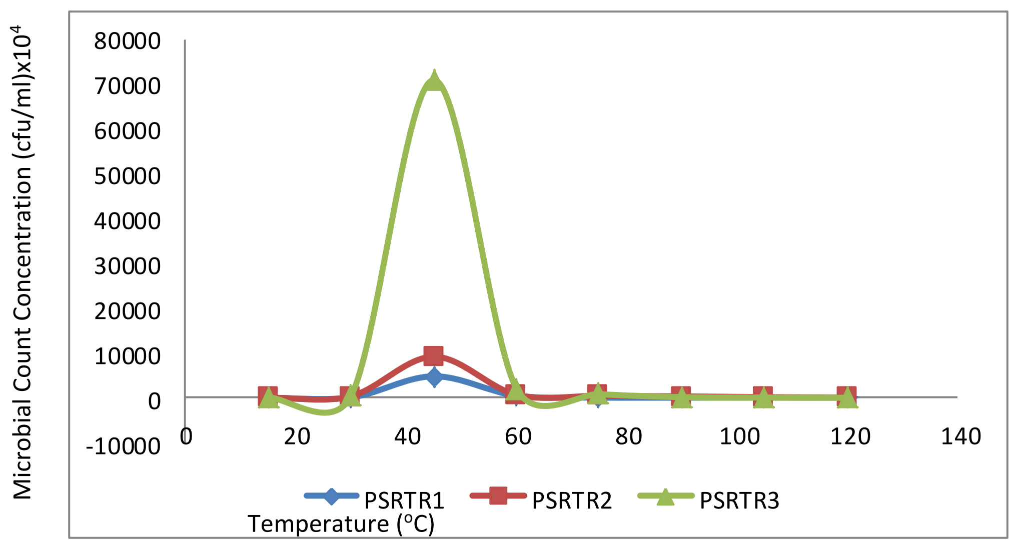

Figure 5 Microbial Count Concentration versus Temperature Effect for PSRT for Packed Bed Unit 1, 2 and 3

Figure 5 evaluates the microbial count concentration of contaminants treatment in a packed bed unit of bio-adsorbent in relationship to temperature effects on the degree of contaminants removal. Indeed, this thesis reveals that the temperature influence bio-adsorbent. Also, the research shows the significance of temperature on the performance of the bio-adsorbent in the packed bed unit connected series. The percentage of contaminants removal is in the ascending order of U1 > U2 > U3 and however the packed bed unit is more effective within the temperature range of 150oC to 45oC. At high temperature range of greater than 45oC and above the degree of contaminants removal are distributed to the various units.

This thesis reveals that there is high penetration of contaminants through the bio-adsorbent placed in the packed bed units. On this note the contaminants that passes through the first bio-adsorbent in the packed bed units (U1) may be trapped in units (U2) or units (U3). If the final outlet concentration of the treated contaminants do not met the World Health Organization Standard (WHO) suggest end product will be subjected with further treatment by the mechanism of recycling using fresh bio-adsorbent packed in the various biounits connected in series. Figure 5 demonstrates the comparison of the microbial count concentration of the HUB isolated and identified in each bio-unit with the effect of temperature reveals the degree of microbial in this order of PSRTR3 > PSRTR2 > PSRTR1.

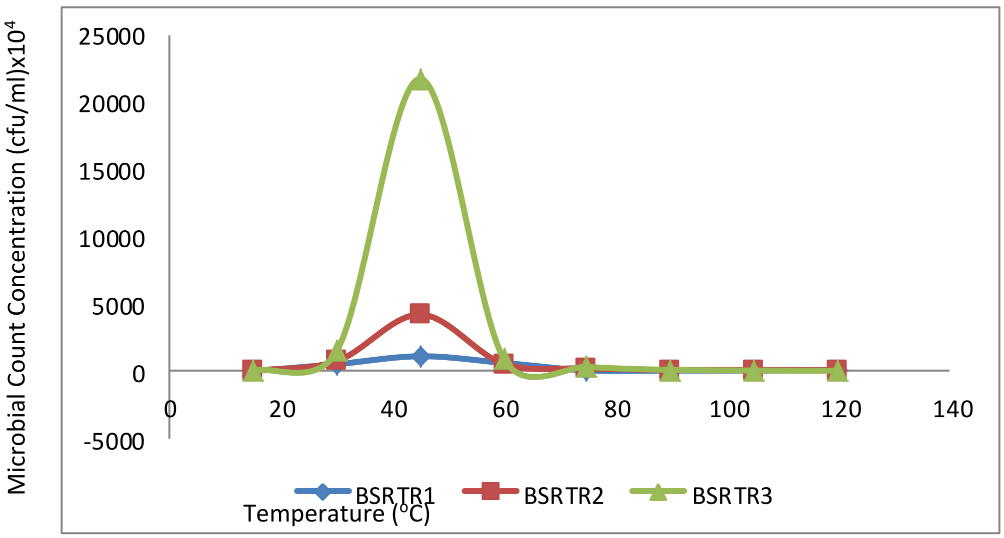

Figure 6 Microbial Count Concentration versus Temperature Effect for BSRT for Units 1, 2 and 3

Figure 6 predicts the resilience of the microbial count concentration on the action of temperature on the treatment of contaminants in a packed bed units connected in series using bio-adsorbent. The effectiveness of the bio-adsorbent is based on the ability of it to reduce the concentration of the contaminants after passing through the packed bed unit. This thesis predicts high removal of contaminants from unit U1, unit U2 and unit U3 within the operating temperature of less 45oC and at temperature greater than 45oC contaminants removal was experienced but the percentage removal is more effective at low temperature as presented in this research work. Indeed, this thesis recommended that the best operating temperature for treatment of contaminated water using bio-adsorbent is within the range of 30oC to 45oC especially when the bio-adsorbent is to be used in the packed bed unit. Figure 6 showcases the comparison of the microbial count concentration of the HUB isolated and identified in each bio-unit with the effect of temperature reveals the degree of microbial in this order of BSRTR3 > BSRTR2 > BSRTR1.

Figure 7 predicts the microbial count concentration of HUB after contaminants treatment from the various units packed bed unit connected in series. The microbial count concentration increases with the range of temperature 15oC to 45oC before sudden decrease as the temperature increases. This research work reveals that the bio-adsorbent in treatment of contaminants removal is more effective at temperature of 45oC. However, organisms that service at temperature less than 45oC are classified as mesophilic. Furthermore, after the temperature of 45oC a decline in microbial population was experienced. These characteristics were observed in all the packed bed unit connected in series.

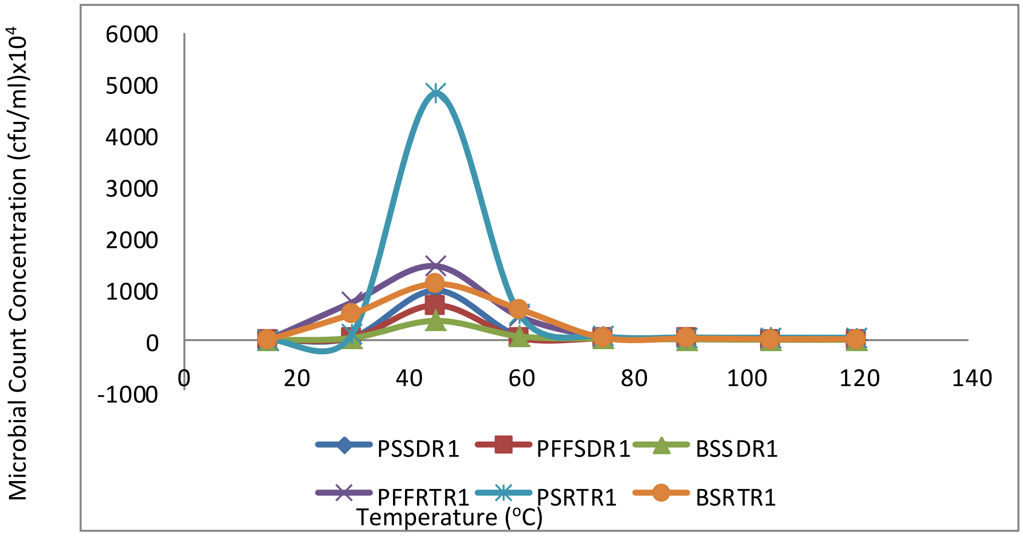

Figure 7 Microbial Count Concentration versus Temperature Effect for PSSD, PFFSD, BSSD, PFFRT, PSRT and BSRT for Packed Bed Unit 1

The thesis also revealed that high percentage of the contaminants are removed at stage 1 of the packed bed units (U1) followed by unit (U2) and final treatment on unit (U3). The microorganisms play an active role in the bioremediation and degradation of the contaminants increase in microbial count concentration reveals increase in contaminants removal in order of U1 > U2 > U3 upon the effect of temperature. Figure 7 illustrates the comparison of the microbial count concentration of the HUB isolated and identified in each unit with the effect of temperature reveals the degree of microbial in this order of PSRTR1 > PFFRTR1 > BSRTR1 > PSRTR1 > PFFSDR1 > BSSDR1. In this case, the plantain fiber of room dried performance was high compared to others in the packed bed unit 1 (U1).

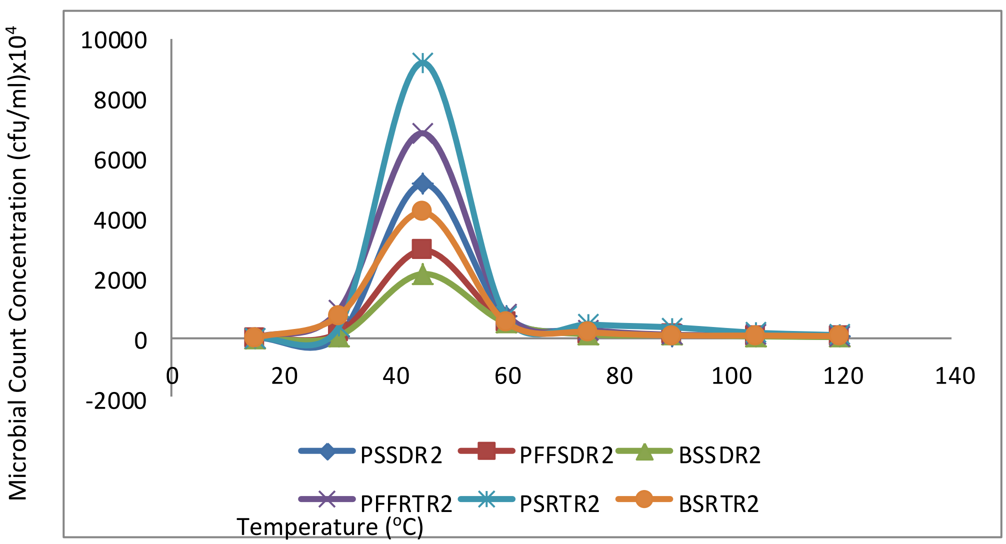

Figure 8 Microbial Count Concentration versus Temperature Effect for PSSD, PFFSD, BSSD, PFFRT, PSRT and BSRT for Packed Bed Unit 2

Figure 8 evaluates the microbial count concentration of contaminants treatment in a packed bed unit of bio-adsorbent in relationship to temperature effects on the degree of contaminants removal. Indeed, this thesis reveals that the temperature influence bio-adsorbent. Also, the research shows the significance of temperature on the performance of the bio-adsorbent in the packed bed

units connected series. The percentage of contaminants removal is in the ascending order of U1 > U2 > U3 and however the packed bed unit is more effective within the temperature range of 150oC to 45oC. At high temperature range of greater than 45oC and above the degree of contaminants removal are distributed to the various unit. This thesis reveals that there is high penetration of contaminants through the bio-adsorbent placed in the packed bed unit.

On this note the contaminants that passes through the first bio-adsorbent in the packed bed unit (U1) may be trapped in unit (U2) or units (U3). If the final outlet concentration of the treated contaminants does not meet the World Health Organization Standard (WHO) suggest end product will be subjected with further treatment by the mechanism of recycling using fresh bio-adsorbent packed in the various units connected in series. Figure 8 showcases the comparison of the microbial count concentration of the HUB isolated and identified in each unit with the effect of temperature reveals the degree of microbial in this order of PSRTR2 > PFFRTR2 > PSSDR2 > BSRTR2 > PFFSDR2 >BSSDR2. In this case, the plantain fibre of room dried performance was high compared to others in the packed bed unit 2 (U2).

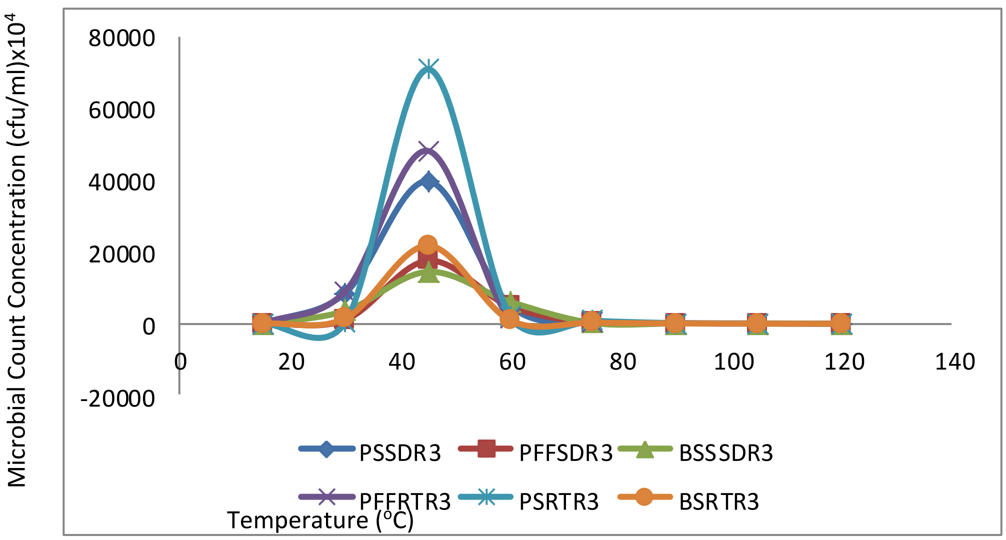

Figure 9 Microbial Count Concentration versus Temperature Effect for PSSD, PFFSD, BSSD, PFFRT, PSRT and BSRT for Packed Bed Unit 3

Figure 9 predicts the resilience of the microbial count concentration on the action of temperature on the treatment of contaminants in a packed bed unit connected in series using bio-adsorbent. The effectiveness of the bio-adsorbent is based on the ability of it to reduce the concentration of the contaminants after passing through the packed bed unit. This thesis predicts high removal of contaminants from unit U1, unit U2 and unit U3 within the operating temperature of less 45oC and at temperature greater than 45oC contaminants removal was experienced but the percentage removal is more effective at low temperature as presented in this research work.

Indeed, this thesis recommended that the best operating temperature for treatment of contaminated water using bio-adsorbent is within the range of 30oC to 45oC especially when the bio-adsorbent is to be used in the packed bed unit. Figure 9 showcases the comparison of the microbial count concentration of the HUB isolated and identified in each bio-unit with the effect of temperature reveals the degree of microbial in this order of PSRTR3 > PFFRTR3 > PSSDR3 > BSRTR3 > PFFSDR3 > BSSDR3. In this case, the plantain fibre of room dried performance was high compared to others in the packed bed unit 3 (U3).

4. CONCLUSION

The research was able to demonstrate the examination of microbial potential in packed bed units connected in series for treatment of contaminated water with crude oil on subject of agro-based adsorbents as projected in this investigation. From the research the following discoveries are highlighted:

1. The microbial growth was significant in treatment unit U1 and this was integrated to the amount of TPH for microbial utilization compared to units U2 and U3.
2. Increase in the microbial growth can be integrated to the available nutrient contained by each of the bio-adsorbent used for the treatment of the polluted water medium.
3. The growth of the microorganisms was experienced on both bacteria and fungi in all the treatment units of U1, U2 and U3
4. The temperature impact on the microbial build up was experienced in both bacteria and fungi
5. This temperature impact influences the decline of some bacteria and fungi at 45oC, 75oC and 120oC
6. The application of bio-adsorbent in treatment of contaminants in a packed bed unit enhanced microbial activity as well as increase remediation

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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